

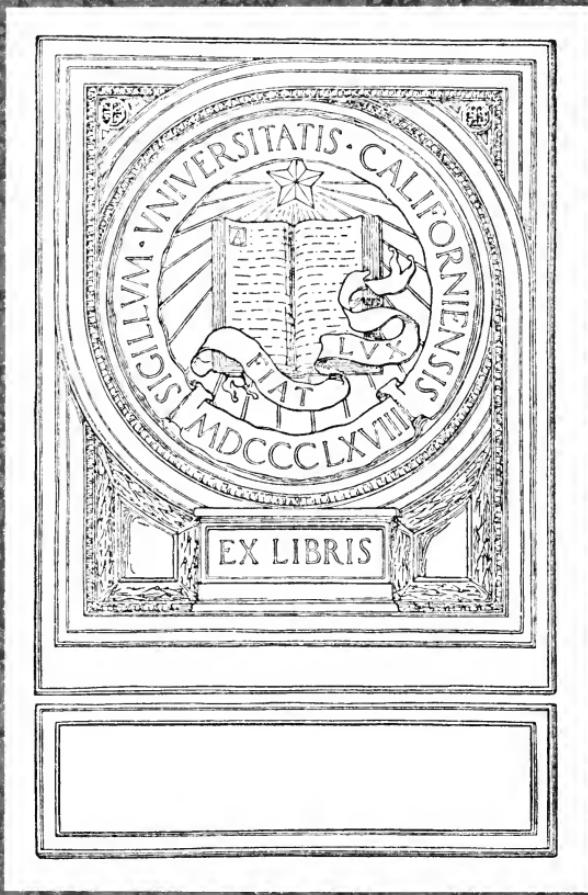
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THE Isthmian CANAL

BY

H. H. ROUSSEAU

CIVIL ENGINEER, U. S. NAVY

MEMBER Isthmian
CANAL COMMISSION

PRESENTED AT THE TWENTIETH ANNUAL
SESSION OF THE TRANS-MISSISSIPPI COM-
MERCIAL CONGRESS

HELD AT DENVER, COLO.

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THE Isthmian Canal.

BY H. H. ROUSSEAU.

*Civil Engineer, U. S. Navy,
Member Isthmian Canal Commission.*

In the days that are to come, the pages of history will mark as a milestone, in the progressive western trend of civilization, the completion of the Panama Canal, which can now be predicted to occur by January 1, 1915.

Its history is an interesting one, and has been over four centuries in the making; but since the first hardy adventurers, pushing westward from their native shores, landed on the American coast, there has been no more doubt that this project would not, as an indispensable factor in the future of the American continent, ultimately materialize, than that those selfsame pioneers would not continue their westward journey overland from the North Atlantic coast to the Mississippi River, thence over broad plains and rugged mountains, and finally, as has long since been seen, reach the Pacific Ocean, carrying with them and leaving in their trail the energy and spirit that have developed and now maintain the American nation.

In these centuries, during which the North American continent has been forging ahead, there has been no uncertainty as to the construction at the proper time of a canal between North and South America. Only three matters have been unknown:

- First. By whom the canal would be built;
- Second. Its location; and
- Third. When it would be built.

Spain, England, Portugal, and France have all embarked upon the work, either directly or by giving aid and encouragement to their representatives, and failed. The time for success had not yet

arrived, for even if the funds with which to prosecute the work had been unlimited, the difficulties were then too great for engineering and medical science to solve.

It was President Grant who first advanced the policy of "an American canal under American control," and it was President Roosevelt who, voicing the sentiments of the entire American people, lent the aid of the United States in undertaking the work, which is being hastened to completion by President Taft.

It is interesting to review the various steps and numerous attempts which have led up to the construction of the canal.

First there was Balboa, who, driven from home by his creditors, landed on the Isthmus of Panama in 1500, where he married the daughter of an Indian chief. In 1513 he organized an expedition that crossed from the Atlantic to the Pacific afoot in twenty-three days over what is now known as the Caledonia Canal route, one of the score of projected routes that have been since advocated at various times by various persons. Old Panama, on the Pacific side, which afterwards became known as the richest city in the world of its time, was settled in 1517, and the highways from old Panama to Nombre de Dios, on the Atlantic coast, and from old Panama to Porto Bello, which were soon afterwards built, became the first regularly traveled routes across the Isthmus, over which passed all the spoils of conquest sent back to Spain from Peru. These highways, paved with stone, furnished ample facilities for the pack trains which traveled over them for many years, and to-day some parts of these roads are in good condition and can be traced for miles through the tropical vegetation in which they remain hidden and unused.

It was in those early days that the idea of a canal took birth, even while the existence of a natural strait was in doubt. A Spanish engineer, named Saavedra, one of Balboa's followers on the Isthmus, is reported to have been its first advocate, in 1517. After studying the subject for years he was about to forward his plans in 1529 to Charles V, King of Spain, when his death occurred. Surveys of the Isthmus with this object in view were ordered, but the work was reported to be impracticable, and with the tools available in those days this was certainly true. Philip II, successor to Charles V, in 1567, sent an engineer to survey the Nicaragua route, who likewise submitted a report unfavorable to the success of the work. In his

perplexity Philip is said to have laid the matter before the Dominican friars, who desired to obey the king's orders, but being unable to report intelligently on such a problem, after searching the Bible quoted the following verse as having direct reference to the Isthmian Canal:

“What God hath joined together, let no man put asunder.” This was sufficient for King Philip, who laid the canal project on the shelf, where it remained through the reigns of his various successors for two centuries after his death.

In 1814, feeling the necessity of reviving its waning prestige in its Central American colonies, Spain entered upon, by decree, the construction of an Isthmian canal, but before any steps could be taken to carry out this purpose her Central and South American colonies obtained their independence. With the successful termination of the revolt of the Spanish provinces Spain passes from the history of the Isthmian Canal, except through furnishing some of the laborers to dig the American canal.

All the enthusiasm of those early days in regard to the canal idea was unavailing for lack of proper tools and sufficient capital. Moreover, the old stone highways filled requirements very well. The Atlantic terminus of the road from old Panama, which passes through Cruces, on the Chagres River, had been changed from Nombre de Dios to Porto Bello about 1597. This route was followed by Morgan in his raid, which resulted in the destruction of old Panama in 1671, two years after he had sacked Porto Bello.

England entered the lists with Lord Nelson and Baron von Humboldt as its representatives, who made researches and reports on the Nicaragua and other canal routes in the latter part of the eighteenth and the early part of the nineteenth centuries. Goethe's far-seeing prophecy, at this time, of American settlement and control of the Pacific coast, and the necessity of an Isthmian canal as a connecting link between our east and west coasts deserves especial attention.

In 1825, President Bolivar, of the Republic of New Granada, gave to a Frenchman, Baron Thierry, a franchise for a canal at Panama, who failed in raising the required capital. President Bolivar then commissioned a British engineer, Mr. J. A. Lloyd, to survey the Isthmus for either a road or canal.

While some negotiations were undertaken by citizens of the United States prior to 1830, the year 1835 really marks the entrance of the United States into the history of the canal, through a resolution introduced in the Senate by Henry Clay, in pursuance of which President Jackson commissioned Mr. Charles Biddle to visit the Isthmus and report on the availability of the different routes for interoceanic communication. Mr. Biddle proceeded to Chagres, the only available Atlantic port, thence to Cruces by boat, and to Panama by mule back. He was much impressed with the advantages and practicability of the Panama route, and afterwards visiting Bogota, with the assistance of Don José Obaldia, the father of the present President of the Republic of Panama, obtained a franchise to build a railroad across the Isthmus. He returned to the United States without making an examination of the Tehuantepec and other Central American routes, as he had intended. On account of the panic of 1837, the United States was not in any condition to finance an undertaking like this, and the matter was dropped.

In 1838 a concession was granted to a French company for the construction of highways, railroads, or a canal across the Isthmus. The Government of France became interested, and sent an engineer, Napoleon Garella, to report on the enterprise. He advocated a canal as the only adequate means of communication across the Isthmus. The concession was, however, allowed to lapse without performing any work, on account of lack of capital.

The attention of the American people was again turned to transportation via the Isthmus by the settlement of the Northwest boundary question, by which we came into possession of Oregon, and by the Mexican war, which added California to our possessions. Communication overland to the Pacific slope was difficult and dangerous, which deflected the main current of immigration via Cape Horn. To render this newly acquired territory more accessible, lines of steamers from New York to the Isthmus and from the Isthmus to California and Oregon were inaugurated by Americans having in view the construction of a railroad as a connecting link across the Isthmus, from which they would derive the greater part of their profits. Securing a franchise therefor from the Government of New Granada in 1848, Messrs. Aspinwall, Stephens and Chauncey entered upon the construction of the Panama Railroad, and after

successfully coping with various financial and physical difficulties opened the road from Aspinwall (now Colon) to Panama in 1855. Under its very advantageous concession, the Panama Railroad Company held exclusive right to construct a railroad or canal in a certain territory, which gave it complete control of the Panama route, which by subsequent modification dated for ninety-nine years from 1867. First-class railroad fare for many years after the road was opened was \$25 across the Isthmus—over 50 cents per mile. The time of passage was four hours. The present first-class fare is \$2.40, and time of transit two hours and a quarter.

The promoters of the Panama Railroad had based its prospects on the advantages which it would afford from shortening the route to California and Oregon, and also to the Orient, and from the development of the Pacific coast. The discovery of gold in California in the latter part of 1848, with its accompanying immigration westward, changed the prospects of the railroad and put it on a firm basis financially and made the enterprise one in which the Government as well as the people of the United States became deeply interested.

Railroad communication across the Isthmus was now finally established and the construction of a canal was relegated to the background, so far as the Panama Railroad was concerned. Meanwhile other canal routes were exploited by a small army of promoters.

Altogether 19 different routes have been suggested and received more or less attention. Of these, the Tehuantepec, Nicaragua, Panama, and Darien projects are the most important, and Nicaragua has been Panama's principal rival in the last thirty years.

The railroad did not in general opinion meet satisfactorily the requirements of interoceanic communication, and, in 1869, the United States again took up the canal question, and President Grant appointed an interoceanic canal commission. Negotiations were entered into between our Government and the United States of Colombia for building a canal, and a treaty was signed in 1870 providing that the work would be undertaken if a satisfactory route could be surveyed. The territory covered by the Panama Railroad Company's franchise was respected, and an examination was made of other less favorable routes, including the Caledonia, San Blas, and Atrato routes, and finally the commission took up the Nicaragua route and reported favorably on it in 1876. But nothing was done, the

United States temporarily lost its opportunity, and the representatives of France stepped in and remained in control of operations for twenty-eight years—until 1904, when they retired, defeated, in favor of the United States.

The Universal Interoceanic Canal Company by which the work was performed was organized and incorporated by Ferdinand de Lesseps in Paris in 1878. The movement in which it resulted was started by a French promoter who secured a concession from the United States of Colombia for the construction of a canal. He transferred his concession to a speculative company called the "International Civil Society of the Interoceanic Canal." De Lesseps became interested and surveys of the Atrato and San Blas routes were made, which were pronounced impracticable. Finally, the Panama route was surveyed and a concession was obtained from the Colombian Government for the construction of a canal on any part of the Isthmus, with the understanding that the company would make satisfactory arrangements with the Panama Railroad Company in case the latter's territory was invaded. De Lesseps convened a congress known as the "International Congress of Surveys for an Interoceanic Canal" in Paris in 1879, which pronounced in favor of a sea-level canal from Limon Bay to Panama Bay, at a cost of \$240,000,000 and time of completion twelve years. Less than 100 delegates of the 135 were present when the sea-level resolution was passed and only 78 voted in favor of it. The Universal Interoceanic Canal Company was then formed with De Lesseps at its head. The control of the Panama Railroad was secured through the purchase of its stock at a high figure—over \$18,000,000. Work was entered upon and pushed vigorously on the sea-level plan. De Lesseps's success at Suez made him a strong advocate of the sea-level type, and a majority of the delegates had been accordingly influenced in their vote on the question. The original capital of \$60,000,000 was quickly snapped up, and the first two years were spent in making surveys, examinations, and other preliminary work.

The first plan adopted was for a sea-level canal 29½ feet deep and having a minimum bottom width of 72 feet. It included a tunnel through the continental divide at Culebra. The currents due to the difference in tides of the two oceans were to be reduced by sloping the bottom of the canal on the Pacific side. No special attention was given

to the Chagres River. Afterwards a tidal lock near the Pacific was provided and also a dam was to be constructed at Gamboa to control the Chagres. The tunnel through the divide was changed, also, to an open cut. Subscriptions for stock had been, meanwhile, called for yearly and were dwindling. In 1887 the evident impossibility of completing the work within a reasonable cost led to the substitution for the sea-level plan, of one involving temporary locks, with the summit level placed above the flood line of the Chagres River, and supplied with water from the Chagres by pumping. Work was continued until 1889 when the company went into bankruptcy. A receiver was appointed and work was suspended on May 15. Over \$260,000,000 had been spent and about 66,700,000 cubic yards of excavation had been accomplished, at a cost of nearly \$4 per cubic yard.

The new Panama Canal Company was formed in October, 1894, and resumed operations on the canal, principally in Culebra cut, in accordance with plans recommended by a commission of engineers. This company continued to do sufficient work to maintain its franchise until all of its rights and property were transferred to the United States Government in 1904. It excavated about 11,400,000 cubic yards. During this time, also, very thorough investigations of all engineering matters pertaining to the construction of the canal were made, which have since proved of great value. The plans of this company provided a sea-level channel on the Atlantic side, about 17 miles in length, from Limon Bay to Bohio, where a dam with a flight of two locks made an artificial lake extending to Bas Obispo. The summit level from Bas Obispo to Paraiso was reached through two locks at Bas Obispo. The level of the summit was 102½ feet above sea level. The depth of water was 34½ feet and the bottom width of the channel 98 feet. The summit level was supplied with water through a feeder from a reservoir formed by a dam at Alhajuela on the Chagres River, about 11 miles above Gamboa. Four smaller locks were located on the Pacific side, the two middle ones at Pedro Miguel being combined in one flight, and the others being located at Paraiso and Miraflores. The locks were in duplicate, each with usable dimensions of 738 feet in length and 82 feet in width. It was contemplated at the proper time to consider the adoption of the alternative plan of making the summit cut deeper and omitting the upper

level. Between Bohio and the sea two diversion channels were provided to take care of floods from the rivers that would otherwise enter the canal.

Progress having practically ceased at Panama under the new French Canal Company, to meet the growing sentiment in favor of more satisfactory interoceanic communication, on March 3, 1899, the Congress of the United States passed an act authorizing the President to make full and complete investigations of the Isthmus of Panama with a view to the construction of a canal to connect the Atlantic and Pacific oceans.

This marks the opening of the last chapter in the construction of the Panama Canal, the end of which is now, by the early completion of the canal, in sight. The commission appointed in accordance with the above act was called upon to investigate particularly the Nicaragua and the Panama routes and to report which was the more practicable and feasible, and the cost. In November, 1901, it reported in favor of the Nicaragua route, considering the demands of the New Panama Canal Company for its franchise and property more than balanced the other advantages of the Panama route. The price fixed by the Panama Canal Company was \$109,000,000. By subsequent negotiations the French company was induced to reduce its price to \$40,000,000, and the commission in January, 1902, submitted a supplemental report in favor of the Panama route. The plan recommended by the commission was for a lock canal, with a sea-level channel from Colon to Bohio. A dam at Bohio, across the Chagres Valley, was to create a summit level 82 to 90 feet above the sea to be reached by two locks. The lake extended to Pedro Miguel, where two locks lowered the level to 28 feet above sea level. At Miraflores sea level was reached through a third lock. The bottom width was to be 150 feet, except in Panama Bay, where it was 200 feet, and in Limon Bay, 500 feet, with turning basins 800 feet wide. The minimum depth was 35 feet. The locks were to be 740 feet long and 84 feet wide.

In accordance with this report, act of Congress of June 28, 1902, known since as the "Spooner Act," authorized the President of the United States to proceed with the construction of a canal by the Panama route, provided arrangements could be made with the New Panama Canal Company for the purchase of its property and fran-

chise for not exceeding \$40,000,000, and provided arrangements could be made with the Republic of Colombia for the control of the necessary right of way. In the event of failure of these negotiations the Nicaragua route was to be adopted. The law provided that the canal should be "of sufficient capacity and depth as shall afford convenient passage for vessels of the largest tonnage and greatest draft now in use and such as may be reasonably anticipated." Appropriations were made to carry out the provisions of the act, and a bond issue of \$130,000,000 was authorized. The bond issue was based on the estimates accompanying the report of the commission of 1901 recommending a lock canal.

Satisfactory arrangements were completed for the purchase of the French company's rights, etc., for \$40,000,000 and negotiations with the Republic of Colombia were carried on to secure other necessary rights and privileges not held by the French company. After a long delay, a satisfactory treaty was formulated, which was rejected by Colombia in 1903.

The province of Panama, an integral part of Colombia, thereupon seceded and organized an independent republic. This resulted in the negotiation of a satisfactory treaty with the new Republic of Panama, including the payment, under certain terms, of \$10,000,000 by the United States to the Republic of Panama. Under this treaty the United States guaranteed the independence of the Republic of Panama and secured absolute control over what is now called the Canal Zone, a strip of land about 10 miles in width, with the canal through the center, and 45 miles in length from sea to sea, with an area of about 448 square miles. The United States also has jurisdiction over the adjacent water for 3 miles from shore. To all intents and purposes it is a perpetual lease from the Republic of Panama to the United States of all governmental rights and privileges in this territory, and yet, strictly speaking, it is not United States soil, for residents therein acquire no rights of United States citizenship and have no voice in United States elections, while citizens of the Republic of Panama residing in the Canal Zone are protected in their electoral rights and are accustomed to go to Panama and Colon to vote in the Panamanian elections. The cities of Panama and Colon and a certain water frontage adjacent thereto, while within the 5-mile limit from the center line of the canal, which bounds the Canal Zone, are excluded

from the Canal Zone and are considered Panamanian territory, although the United States has, under the treaty with the Republic of Panama, the right to regulate sanitary matters therein, and, if necessary to preserve order, to enter those cities with armed forces and take possession of them.

There is no doubt that the United States received ample consideration for the \$40,000,000 paid to the New French Canal Company, viz:

Excavation by the French useful in the present project, estimated at not far from 40,000,000 cubic yards, has been conservatively valued at \$27,500,000.

The Panama Railroad, with its franchise and all rights, etc., which had been purchased for over \$18,000,000 by the old French company, was valued at \$7,000,000, the par value of outstanding stock.

About 43,000 acres of land went with the Panama Railroad property and 33,000 acres were acquired from the French Canal Company, a total of 76,000 acres.

The maps, drawings, and all other technical data that were taken over from the French company were valued at \$2,000,000, and buildings, machinery, etc., at \$3,500,000; the whole totaling \$40,000,000.

Up to the present time French machinery, conservatively appraised at \$1,000,000, has been used, and the net value of French buildings which are in use, not including cost of repairs, is not far from \$2,000,000.

The principal point of excellence in regard to this French machinery, which has weathered so well on the Isthmus for the past twenty-five years, is the quality of material and workmanship. In design, speed, and size of units it is far behind the present standards. However, it was the best of its kind in that day.

In consideration of the \$10,000,000 paid to the Government of Panama for the rights conveyed, there was turned over to the United States, in addition, all public lands in the Canal Zone, amounting to about 120,000 acres. This makes the United States Government the direct owner of 70 per cent of the land in the Canal Zone, the remaining 30 per cent being held by private owners, mostly citizens of the Republic of Panama. The United States exercises governmental rights over all.

The act of Congress of 1902 placed entire jurisdiction in regard to the construction of the canal in the hands of the President of the

United States, the particular functions in regard thereto being exercised by a commission composed of seven members appointed in accordance with the act of Congress, presided over by one member as chairman. For convenience in administration the canal operations have been placed under the Secretary of War.

The formal transfer of the property of the French Canal Company to the United States took place on May 4, 1904, and the first two and one-half years thereafter, or until January, 1907, were devoted largely to the work of preparation, consisting of building up a suitable organization; procuring the necessary plant and equipment; combating insanitary conditions, eliminating yellow fever, and reducing malaria; reconstructing and double-tracking the Panama Railroad; improving terminal facilities, and making provision for adequate and efficient transportation to the Isthmus from the United States, a large item in itself; the design and building of suitable quarters for the army of nearly 5,000 American employees and over 25,000 laborers; introducing a stable form of civil government and administration, including courts, schools, police, fire department, etc.—in other words, doing everything necessary to transform the jungle, infested with mosquitoes and various low forms of animal and vegetable life, injurious to health, into a comparatively healthful country with all the advantages and conveniences and equivalent conditions of life as regards comfort, food, and quarters, as are enjoyed by the average citizen in the United States. All of this took time and a great deal of money, but it has resulted in advancing the condition and developing the territory in question, which was practically in the same state that it was in the sixteenth century, to the plane of twentieth century civilization—and all in two and one-half years.

Attention was early drawn to the insanitary condition of the cities of Panama and Colon, and it was soon perceived that if a pestilence should obtain a foothold in those cities it would seriously affect canal work. To eliminate this danger, Panama has been provided with substantial brick pavements, has been well sewered and furnished with a supply of wholesome drinking water. The city of Colon has been transformed from a swamp into a town likewise comparable with a city of the same size in the United States, so far as pavements, water supply, and sewers are concerned. This work has cost about \$2,275,000, and at the last session of Congress

\$800,000 more was specially appropriated to carry on the additional work which has become necessary on account of the growth of the suburbs of Panama and the necessity of extending the building limits of the city of Colon, due to the large increase in population. Under the terms of the treaty the cost of all of this work is an obligation which the Republic of Panama assumes and will repay to the United States with interest, through water rates which are collected directly by the United States and turned into the Treasury. Payments at present are being made at the rate of \$136,000 per annum. The sanitary conditions in these two cities and the advantages of good pavements are an object lesson to all travelers from South and Central America which is bearing its results, and the shipments of paving brick from the United States to South America have increased as a result of this work.

The situation in the city of Colon as regards ownership of land is peculiar. It is practically all owned by the Panama Railroad under its original franchise, under the terms of which ownership reverted to the United States of Colombia at the expiration of its franchise. This land, therefore, can not be sold by the Panama Railroad. By the treaty of 1904 the Republic of Panama, as the successor of the Republic of Colombia, transferred to the United States all of its rights accruing at the expiration of this franchise. Meanwhile the United States had purchased the Panama Railroad from the French Company. Therefore the present condition is that the United States, through the Panama Railroad, is the owner of land in Colon, but can not, under the railroad's franchise, sell it. This land, moreover, which it owns, will, through the expiration of the franchise of the Panama Railroad in 1966, be turned over to the United States, and the condition will arise of one government owning land in a foreign country. The land is under the jurisdiction and laws of the Republic of Panama, as it is not within the limits of the Canal Zone. This situation, however, can and will be easily straightened out, and ultimately some disposition will be made of the property, which is considered to be, even at the present time, very valuable. This land is now leased by the Panama Railroad in lots to the highest bidder for a term of years. Rents are high and lessees expect to get returns of 50 per cent and

upward per annum. The Panama Railroad, through its corporate powers, has proved a very useful and necessary adjunct in the construction of the canal, and it would disarrange and be a great hindrance to the work to have its charter canceled before the completion of the canal.

During the period of preparation, work was not neglected on the canal excavation, and every effort was made to make the "dirt fly." At first, the only tools available were some old French excavators, locomotives, dump cars, and drills. Modern American equipment, consisting of dredges, steam shovels, cars, locomotives, etc., was put into service as fast as it could be purchased and hurried down to the Isthmus. During 1904, 1905, and 1906 material was excavated as follows:

	Cubic yards.
1904.....	243,472
1905.....	1,799,227
1906.....	4,948,497
 Total.....	 6,991,196

Meanwhile the type of canal came up again, and in consideration of the international importance of the canal President Roosevelt appointed a Board of Consulting Engineers consisting of 13 members, including representatives of 5 European countries, and 8 Americans, which met in Washington in June, 1905. Eight members of this board, including the five foreign engineers, recommended that a sea-level plan be adopted. Five American engineers recommended a lock canal. Of the eight in favor of the sea-level canal, one, an American, stated that if it were a commercial enterprise for a private company he should vote for a lock canal. One of the foreign engineers qualified his vote in favor of the sea-level canal, in the report, by stating that he considered a high-level lock canal practicable, but that considerations of cost and time of completion with such a canal should not be taken as the governing considerations. This, notwithstanding the instructions to the board from the President that in addition to reporting on a feasible plan, the prime consideration was the shortest time of completion and a minimum amount of work; that is, minimum cost. In strict accordance with these instructions the vote would have been 7 for a lock canal and 6 for a sea-level canal. The members of the Isthmian Canal Com-

mission, with one exception, recommended to the President the adoption of the 85-foot level lock canal recommended by the minority of the Board of Consulting Engineers and indorsed by the then Chief Engineer of the Commission, for the following reasons:

1. Its first cost will be much less—nearly \$200,000,000.
2. It will be completed much more quickly—fully six years.
3. Its cost of operation and maintenance, including fixed charges, will be less by several million dollars per annum.
4. It provides greater safety for ships and less danger of interruption to traffic, by reason of its wider, straighter, and deeper channel.
5. It provides quicker passage for large ships and large traffic.

In his message to Congress of February 19, 1906, forwarding the board's report the President stated:

"The law now on our statute books seems to contemplate a lock canal. In my judgment a lock canal as herein recommended is advisable."

On June 29, 1906, the construction of a lock type of canal was authorized by Congress in accordance with the general plans of the so-called minority of the Board of Consulting Engineers and the work has since been carried on along these lines. During the three years which have elapsed, nothing has occurred on the work which has occasioned uneasiness on the part of those most intimately and responsibly concerned with the execution of the work, or which has caused them to doubt either the wisdom of this choice or the ultimate success of the undertaking; and at this late date with the lock canal far advanced a discussion on the relative merits of a lock versus sea-level canal is about as much out of date as a last year's spring bonnet, and is as interesting and illuminating a subject of conversation for those who are well informed in regard to canal work as the weather in Labrador in December. There is no engineering, commercial, or military reason for considering a sea-level plan at this stage of the work; and those who desire to discuss a dead issue like this, even from an academic standpoint, should first be required to give a better reason for making a change than one that might suffice for the selection of a suit of clothes of a particular cut or fabric, but which is not sufficient for the people of the United States who have already spent over \$20,000,000 toward the construction of locks, which would be wasted were a change to a sea-level canal now made. The whole

matter may be summed up in the quotation from President Roosevelt's message to Congress last winter:

"That hereafter attack on this type, the lock type, is in reality merely attack upon the policy of building any canal at all."

The 85-foot lock canal which is being built consists of a sea-level entrance channel 7 miles long and 500 feet wide on the Atlantic side to the foot of Gatun locks. On the Pacific side there is a corresponding sea-level channel to Miraflores nearly 8 miles long. For 15 of the 50 miles the canal will be at sea level. At Gatun the 85-foot lake level is obtained by a great dam. The lake is confined on the Pacific side by a smaller dam between the hills at Pedro Miguel, 32 miles away. These two dams make a great lake 85 feet above sea level, with an area of 164 square miles. Ships pass from the sea level to the lake level, and vice versa, at Gatun by a series of adjoining locks, "in flight" as it is called, three in all, each with a lift of 28½ feet. The locks are in duplicate. On the Pacific side at Pedro Miguel, instead of dropping down at once to the sea level, there is one lift, with duplicate locks, by which vessels are lowered to a small lake called Miraflores Lake, which is 55 feet above the mean level of the Pacific Ocean. One mile from Pedro Miguel, through Miraflores Lake, are the Miraflores locks, where by two lifts, with locks in duplicate, vessels reach sea level on the Pacific side.

From deep water to deep water the distance is about 50 miles and it is expected that a vessel can easily make the transit within less than twelve hours.

The Atlantic channel has a depth of 41 feet below mean sea level, and the average range of tides is not over a foot. On the Pacific side the tides have a range sometimes as much as 20 or 22 feet, and in order to provide ample depth the channel is to be dredged to a depth of 45 feet below mean sea level. The elevation of both oceans is the same at half tide. At extreme high tide, therefore, the Pacific Ocean is 10 feet above the Atlantic and at low tide 10 feet below.

Gatun Lake will be a body of fresh water, and its level will be maintained at practically a constant height by the rivers which flow into it. The principal river is the Chagres, which rises in the hills to the east of the canal. It catches all the rain which runs off of an area of about 1,200 square miles. A second large river is the Trinidad, which will flow into the lake from the west. The Trinidad River has

a drainage area of 340 square miles. Its headwaters extend within sight of the Pacific Ocean.

Elaborate investigations and observations have shown that the annual rainfall is entirely sufficient to keep the lake amply supplied. The rainfall averages 100 inches per annum, varying from 120 to 140 inches on the Atlantic side to 60 to 80 inches on the Pacific. The rainy season extends from April to December, during which time practically all of the rain falls. From January to April there is little or no rain.

Evaporation will be one source of loss of water from Gatun Lake and averages not far from one-seventh of an inch per day, or 50 inches per annum. Water will be required to pass vessels through the locks and will also be used, so far as available, in generating electric current for use in lighting, in furnishing power for canal operations, and for the future operation of the Panama Railroad. This will be accomplished by installing a hydro-electric plant at Gatun, and making available the energy due to the 85 feet head of water. Any surplus water will be disposed of by allowing it to flow over a spillway, which is merely a large waste-weir.

In steaming through Gatun Lake, from Gatun to Pedro Miguel, a distance of 32 miles, vessels will traverse a channel varying from 1,000 to 300 feet in width and from 75 to 45 feet in depth. For the first 8 miles no digging is necessary, the natural elevation of the ground being so low that it is only necessary to clear the ground of trees and underbrush.

At Bohio there are a few high points to level off, and some of this work is being done by "task work" with pick and shovel. The thousand-foot channel continues for 15 miles from Gatun, enabling vessels to maintain full speed.

Toward Tabernilla the banks of the Chagres River and the adjacent land to be used as the canal channel rise above elevation +40. The ground will be excavated to that elevation in order that the depth of water in the entire channel may not be less than 45 feet. From Tabernilla the channel continues 800 feet wide for 4 miles, and thence to Bas Obispo 500 feet wide for a distance of about 4 miles. Many million cubic yards were excavated by the French between Tabernilla and Bas Obispo which will be useful in the present project. Between the Atlantic Ocean and Tabernilla none of the

French excavation enters into or is useful to the present plan except for construction purposes.

Between Tabernilla and Bas Obispo the Chagres River, pursuing its winding course, crosses the line of the canal not less than 15 times. At Bas Obispo the Chagres River turns abruptly to the northeast and the canal enters the 9-mile cut through the Cordilleras, which form the backbone of the continent, where the greatest amount of excavation is being done, and which is generally known as "Culebra cut." This cut ends at the Pedro Miguel locks. The minimum bottom width of the canal prism is 300 feet and the depth of water will be 45 feet. In general, the line follows the old French canal in this section, which took its course up the valley of the Obispo River to the deepest part of the cut at Gold Hill, whence it entered and descended the Pacific slope along the line of the Rio Grande River.

At Gold Hill, near Culebra, the highest point on the center line of the canal, the elevation was 333 feet on the axis of the French canal, 312 feet on the present axis (80 feet to the west), and 303 feet at the low point of the saddle or depression between Gold Hill on the east and Contractor's Hill on the west. The French began cutting through Gold Hill on the east side of the canal at elevation 534, which is the highest elevation where work was carried on. In this section of nearly 9 miles the French removed with their comparatively small excavating machines and by pick and shovel over 24,000,000 yards of material, most of which is useful in the present plan, including a large amount of soft overlying earth and clay. The present plans call for the removal of about 89,600,000 cubic yards between Gatun and Pedro Miguel, of which 77,700,000 is in "Culebra cut," in addition to what the French took out; 35,700,000 yards had been removed from Culebra cut to August 1, 1909.

The end of Gatun Lake is reached at Pedro Miguel locks. Miraflores Lake is a small body of water of less than 2 square miles in area, which is kept full by water entering with vessels through the Pedro Miguel locks, and also from water from the Rio Grande and Cocoli rivers, which flow into it. A spillway is located to the east of the Miraflores locks to dispose of any overflow. After passing through Miraflores locks vessels have a straight channel 8 miles in length to the Pacific.

It is thus seen that the present plan provides broad, deep channels, with a minimum of curves and bends.

The average width of channel will be about 650 feet, about three times as wide as the average width of the sea-level canal as proposed and estimated on, at much greater cost. The minimum bottom width of the channel will be 300 feet through Culebra cut. The width for the sea-level canal in earth was intended to be only 150 feet with sloping sides, and 200 feet in rock through Culebra cut with vertical sides.

The principal advantages derived from the raised lake level formed by dams at Gatun and Pedro Miguel are:

(1) The amount of excavation is enormously reduced, and the cost and time correspondingly diminished, even when the cost of the dams and locks is considered.

(2) Another most important advantage, and in fact a necessity, is the ease with which the rainy season floods of the Chagres and other rivers will be controlled by Gatun Lake. The dams at Gatun and Pedro Miguel will raise the water sufficiently to cause the lake to extend 4 or 5 miles above Gamboa. The Chagres River in the dry season is a peaceful, insignificant stream, at Gamboa not over 300 feet wide, and 2 or 3 feet deep. As a result of the torrential rainfall and the precipitous nature of the watershed, especially in its upper reaches, it is subject to large and rapid variations in height. At Gamboa the maximum rise has been nearly 40 feet within a period of twenty-four hours, which transforms it into a rapid, riotous stream, and it many times overflows its banks and floods the surrounding country. The maximum discharge recorded is considerably more than 100 times as great as the low-water discharge during the dry season. Gatun Lake will curb the floods of the Chagres, and the severest storm will have no more effect than to raise its level a foot or two.

(3) A third advantage is that a large portion of the silt and gravel which would be otherwise carried down into the canal past Gamboa will be deposited, owing to the slackening of the current, above Gamboa, outside of the canal prism.

By thus damming the outlet of the Chagres, the formation of Gatun Lake will provide the simplest, most practicable, and most desirable solution of the most perplexing engineering problem arising in connection with the construction of the canal.

The Atlantic and Pacific entrances of the canal will be fully protected, on the Atlantic side by a stone breakwater 2 miles long in 44 feet of water at the outer end, extending northeastward from Toro Point Light-House. The entrance channel will be likewise protected on the east side by a similar breakwater about three-quarters of a mile in length. The construction of these breakwaters has not yet been undertaken, as it was not fully decided until last February that they would be necessary. During the winter months occasional storms from the north occur, locally termed "northerns," of such violence that all vessels have to leave Colon harbor, which is at present unprotected. Such storms, in the absence of breakwaters, would render entrance to and egress from the canal unsafe. The breakwaters will also provide a safe harbor and protect the channel from shoaling.

The Pacific side is never visited with any storms of sufficient duration and violence to require any special protection. The water is quite shallow for some distance from the shore, and the set of the current from the northeast is at right angles to the entrance channel and deeply laden with silt; the tendency is for large quantities to settle in that part of the canal channel, causing rapid deterioration of same. To prevent this shoaling, as well as to dispose of a large amount of spoil from the Culebra cut, a dike or breakwater is in the process of construction from the mainland at Balboa to Naos Island, one of a group of small islands about 4 miles from shore. This dike east of the canal is more than half completed, and the benefits arising from it in preventing the shoaling of the canal channel are very marked, and when it is entirely completed the shoaling resulting from these cross currents will be eliminated.

The present roadbed of the Panama Railroad will be submerged for many miles by Gatun Lake. In order to provide communication by rail across the Isthmus after the completion of the canal, and enable the railroad company while it exists as a corporation to comply with the requirements of its franchise, the railroad is being practically entirely rebuilt on a new location on higher ground to the east of the canal. The cities of Colon and Panama being both on that side, the railroad will therefore not cross the canal. From Gatun the railroad makes a wide circuit around Gatun Lake, crossing the Chagres River on a steel bridge, over a quarter of a mile in length, at Gamboa, and passes through Culebra cut on a broad bench or berm 10 feet above

the level of the lake. The reconstruction of the Panama Railroad is being paid from a special appropriation for the purpose. It is an undetermined matter how much through business will fall to the Panama Railroad after the completion of the canal. The local business between the cities of Panama and Colon and intermediate points should be sufficient in itself, however, for the road to operate without loss. It is expected in time that it will be operated by electricity furnished from the hydro-electric plant at Gatun spillway.

Such is a general description of the plans recommended by the minority of the Board of Consulting Engineers in 1906, and these plans have been since followed throughout with such approved modifications in details as have been considered desirable to obtain the best results with the least expenditure of money. Among the changes are the following: The size and capacity of the canal have been increased in view of the large increase in size of war vessels which has recently taken place. This applies to the change in width and length of locks from 95 by 900 to 110 by 1,000 feet; and the width of channel from 200 to 300 feet through a large portion of Culebra cut. The location of the breakwaters on the Atlantic side has been changed. Likewise, from considerations of military defense and lessened cost, the Pacific locks have been moved inward from Balboa to Miraflores. This latter change was suggested in the report of the original board as being among those which should receive consideration. Every step in the construction has been carefully watched and studied not only by those on the ground who are responsible for its execution, but in addition thereto committees of the most distinguished engineers in the country have at various times made independent investigations on the ground and reports on particular points connected with the construction of locks and dams. The reports of these independent consulting engineers, in expressing the unanimous opinions of their members, have indorsed in every respect the present plans.

The present Isthmian Canal Commission assumed office in April, 1907, and has since been located on the Isthmus in direct contact with the work, taking it up where the labors of Mr. John F. Stevens, as Chairman and Chief Engineer, left off.

As at present constituted it numbers five engineers, with two other members acting as heads of the departments of Civil Administration and Sanitation, respectively.

The operation of the Panama Railroad Company is under the immediate charge of a General Manager. All of the work of the Commission and the Panama Railroad Company is under the complete and direct control of the Chairman and Chief Engineer of the Commission, which has contributed very largely to the efficiency and the smooth, steady progress of the work.

The plan of organization of the Engineering Department divides all construction work into three geographical districts, each under a Division Engineer with full control over and responsibility for all engineering work in his district. These divisions are:

- (1) The Atlantic division, extending from deep water to Gatun Lake, including the Gatun locks and dam.
- (2) The Central division, extending from Gatun to Pedro Miguel.
- (3) The Pacific division, extending from Pedro Miguel to deep water in the Pacific Ocean.

In general, the work may be divided into three classes:

- (1) Wet excavation, viz, excavation performed by dredges. This amounts to about 12 per cent of the total work.
- (2) Dry excavation. This includes all material (rock and earth) removed by steam shovels and other power excavators, or by pick and shovel. This comprises 49 per cent of the work.
- (3) The third class of work covers the construction of locks, dams, and spillways. The dams make the lakes, the locks enable vessels to pass from the sea level to the lake level, or vice versa, and the spillways take care of the overflow from the lakes. These comprise 39 per cent of canal construction work.

A brief description of the different classes of work will be given:

- (1) Wet or dredging excavation amounts to about 73,000,000 cubic yards. One million yards is contained in a cube 300 feet on each side; 73,000,000 would be equivalent to a cube measuring about a quarter of a mile on one side. It consists of soft silt, earth, clay, coral, and hard rock. From 12 to 14 dredges are kept at work, and their monthly output is not far from 1,300,000 cubic yards. They include two new seagoing suction dredges, the *Culebra* and *Caribbean* of a type common in the United States, that draw the material up into bins in their own hulls by centrifugal pumps. When these bins are full, they steam to the dumping grounds, empty by opening bottom gates, and return for another load. These dredges work night

and day, stopping only for fuel and repairs. Owing to their method of operation and the material they handle, they have the largest output at the least unit cost of any of the dredges. Upon the completion of the canal it is expected that these dredges will be kept on the Isthmus for use on any small amounts of dredging that might be required for maintenance work.

Seven old French ladder dredges of Scotch and Belgian make which have been rebuilt are giving very satisfactory service in spite of the small size of their buckets (one-half yard capacity each) compared with the size of dredges now built. The output of these is hardly half that of the seagoing suction dredges. These ladder dredges discharge the spoil by chutes into self-propelling French barges called "clapets," and American scows which are towed to the dumping ground by tugs. Thirteen French clapets and a half dozen barges serve the stationary dredges with the aid of 4 tugs. There are also 3 dipper dredges and several clam-shell dredges with 5-yard buckets, and 1 Lobnitz rock-breaker consisting of a large ram mounted on a barge of suitable size, which is used to fracture and break up the rock on the bottom, which can then be easily removed by dipper or clam-shell dredges. Three sizes of rams are used, weighing from 10 to 19 tons and from 30 to 50 feet in length. When raised from 4 to 10 feet above the water and then dropped, they break the rock to a depth of 3 feet. Experience with this rock breaker has not demonstrated its superiority or economy as compared with subaqueous blasting.

The construction of the Gatun dam and locks also requires pipeline suction dredges and a large transportation equipment.

To rebuild, operate, and repair the fleet of vessels required to carry on dredging and transportation operations, the old French shops at Cristobal and Balboa have been remodeled, enlarged, and supplied with such new and improved equipment as has been found necessary to perform the required work. To make under-water repairs and to scrape and paint the exterior of the hulls, the French had an old dry dock cut out of the solid rock at their shops at Cristobal. This dock has been rebuilt and enlarged and lined with concrete and now is capable of docking a vessel 298 feet long, 50 feet beam, and 15 feet draft. Spanning the dock is a Gantry or movable overhead crane. Several hundred men are employed at these shops.

Vegetable and animal life in these tropical waters are particularly active in attacking the hulls of vessels, making it necessary to dock and paint them at frequent intervals.

On the Pacific side, the Balboa shops perform the same offices for the Pacific fleet at work on that part of the channel. There is no dry dock on that side, and a marine railway is used for the small vessels. Advantage is also taken of the large range of the tides, which permits a vessel to be placed on a "gridiron" at Balboa at high tide; the tide receding lifts the vessel out of the water and permits any work to proceed which can be accomplished before the next high tide. For vessels like the seagoing dredge *Culebra*, it has been customary to run them broadside on the smooth sandy beach at Naos Island at high tide, where they can be painted and repaired as the tide lowers.

In the Pacific division, from the foot of Miraflores Lake southward about 2 miles, there are about 11,300,000 cubic yards of material, mostly dark loam, overlying 1,600,000 cubic yards of hard rock, which will have to be removed. Successive attempts with dredges have shown that it is not practicable to handle the material overlying the hard rock by this method with as great economy as by adopting the hydraulic method which has been developed and used with such success in the western States. It is proposed by this plan after throwing a dam across the channel, 2 miles below the locks, to attack the material with large jets of water under sufficient pressure to break it up and carry it to pools or sumps, whence the combined water and material will be removed by powerful centrifugal pumps having a capacity of 30,000 gallons per minute.

(2) *Dry excavation.*—To the casual visitor to the Isthmus, operations in connection with dry excavation are the most spectacular and interesting of any work in progress. The methods are somewhat similar to those in use in the United States, but nowhere else in the world have excavating operations been carried on on such a large scale and in the precise manner followed on the Isthmus. Some of the machines used have been developed as a result of the experience gained on the work. The construction of the locks involves in itself a large amount of excavation—about 10,000,000 cubic yards. This may be considered a part of the lock construction, and dry excavation under this head will be limited to the prism proper. About

93,000,000 cubic yards are involved, equivalent to a cube measuring about 1,380 feet, or over quarter of a mile on a side, or sufficient to cover 90 square miles with a layer 1 foot thick. Forty-four million yards, or about 47 per cent of this work, had been accomplished to August 1, 1909. Dry excavation is carried on almost exclusively with steam shovels, and at the present time about all of the soft overlying material has been removed, and the rock remaining requires blasting before it can be loaded on the cars. The present method of work is the result of three years' experience. From 50 to 60 steam shovels are being worked on the prism excavation with dippers varying in capacity from $2\frac{1}{2}$ to 5 cubic yards. The other shovels are engaged on the lock and dam excavation at the rock quarries and on the Panama Railroad. The work is divided up into sections, the work in each section being under a superintendent who is responsible for all the work therein, and who is held strictly accountable for the daily output in his section.

The work accomplished in Culebra cut by the French, in general, was to make a deep, narrow cut, and in 1904 the summit near Gold Hill was 193 feet above sea level, having been reduced 140 feet by the French, and an additional cut of 153 feet was necessary. The first work undertaken by the Americans was to widen the cut to full dimensions before going any deeper. The work accomplished to date has consisted of this widening, and in addition the old summit level at Gold Hill has been lowered to elevation +120. At the ends of Culebra cut (Bas Obispo and Pedro Miguel) the excavation has been practically completed to the full depth—elevation +40. At the present summit level at Empire the cut will be made 85 feet deeper. For the purpose of drainage, the bottom slopes uniformly north and south from the summit, 23 feet per mile to the north and 36 feet per mile to the south. Loaded trains pass down grade each way from the summit on their way to the dumps. The present line of the Culebra cut traverses what was originally the valleys of the Obispo, Rio Grande, and other rivers which drain the surrounding country. To prevent the flooding of the cut and interruptions to the work, as well as to reduce the wash of the banks, the canal channel has been paralleled on each side from Gold Hill north to Bas Obispo, a distance of about 5 miles, by smaller artificial channels or canals,

called technically "diversions," which turn aside and convey into the Chagres, at Gamboa, on the east side of the canal, and at Matachin, on the west side, the storm waters that would otherwise flood Culebra cut north of the continental divide. The construction of these diversion channels would usually be considered work of more than ordinary size. The Obispo diversion has a bottom width of 50 feet, is $5\frac{1}{2}$ miles long, and extends from Gold Hill on the south to the Chagres River on the north. It was completed two months ago, and involved the removal of over 1,000,000 cubic yards of material. The deepest cut was about 95 feet; $1\frac{1}{2}$ miles of earth dikes were constructed. The diversion has been designed to carry a maximum flow of 6,000 cubic feet per second. On the west side of the canal there is a similar smaller diversion, from Empire north to beyond Bas Obispo, in which the storm waters flow partly through a natural channel, partly through an artificial channel built by the Americans, and also through an old French tunnel and channel at Bas Obispo. To the south of Gold Hill the drainage from the west, including the overflow of the Rio Grande reservoir, is carried off in the bed of the Rio Grande River and an old French diversion channel. The remainder flows from the east into the cut and will be permitted to flow through the Pedro Miguel locks as soon as the floors are laid; meanwhile it runs through an old culvert under the abandoned railroad to the west of the locks, which has been lowered sufficiently to effect this. At the north end of the cut the low-water level of the Chagres River is at elevation 43 and of the finished canal 3 feet lower, viz +40. The Chagres River has been shut off by a dike with drain pipes at different elevations, which will free the cut from water by gravity in case the dike is overflowed. Under ordinary working conditions three large pumps will remove the water.

At various points along the banks of the Culebra cut the excessive rainfall and the character and slope of the material results in the movement of soft material on layers of slippery clay. These moving masses of material are called "slides." All estimates and calculations for work have provided for the removal of a considerable amount of material which thus slips into the prism. The best known slide is the Cucaracha slide, just south of Gold Hill, which has been a source of annoyance since the days of the French, in 1884.

It was then 800 feet in length and covered an area of about 6 acres. It has since extended until the material involved is about one-half a mile long and covers an area of about 27 acres. Over 700,000 cubic yards are in motion. In 1907 the maximum movement was 14 feet in twenty-four hours. This movement turned over a steam shovel and buried another. One hundred and thirteen thousand cubic yards, with a glacier-like motion, moved into and across the cut, completely filling it up for the time being. The French tried elaborate drainage systems, which proved inadequate. Removal of the material is the only effective remedy. There have been during the past year slides at thirteen different points and 884,000 cubic yards of material have been removed; about 1,000,000 cubic yards are still in motion and will eventually have to be handled. While annoying, and in themselves of some importance, when compared with canal operations as a whole, these slides dwarf into insignificance, and will affect the total amount and cost of the work by less than 1 per cent. All the banks stand up well, and it is the shallow top layer of soft earth and disintegrated rock that is causing the trouble. Undoubtedly before the canal is completed these banks will be so-covered with tropical vegetation as to be permanently held in place.

The various excavating operations are successively as follows: Drilling, blasting, loading, transporting, and dumping.

Tripod drills are used for shallow holes; well or churn drills for the deeper holes; and hand drilling only for a few isolated holes. Compressed air furnishes the power to the drills at 80 pounds pressure. Each shovel is preceded by a battery of from 4 to 12 drills, covering a field from 30 to 40 feet wide, which keeps well ahead of the shovel. Holes are drilled from 15 to 30 feet deep and from 6 to 16 feet apart, depending upon the material and conditions. Each hole is loaded with a charge of from 75 to 200 pounds of dynamite, 45 and 60 per cent dynamite being used principally. One million pounds of dynamite are being used monthly. After being loaded, the holes are connected up in parallel and discharged by electric current. While the greatest care practicable is taken in all operations connected with the handling of dynamite, a number of accidents have occurred and a number of lives have been lost, mostly alien laborers. The most serious explosion occurred at Bas Obispo last December and resulted in 24 deaths,

most of them laborers. It was a premature explosion of 22 tons of dynamite, loaded in 53 holes. The cause of the explosion has remained obscure. One theory was that the water in the holes being slightly acid tended to liberate the nitroglycerine, which being in an extremely unstable condition exploded from some small shock or vibration due possibly to a distant shot or blast. Some of these holes had been loaded several days before the explosion. In order to be on the safe side no holes are loaded now which can not be fired the same day. The large blasts break the rock into fragments small enough to be handled by the steam shovels. Any large pieces are broken into smaller fragments after the main blast by what are called "dobie" blasts, consisting of a small quantity of dynamite laid on the surface of the rock, covered with clay, and discharged by fuse. During the first operations black powder was tried and discarded. During the greater part of the year the holes when loaded are full of water. Power to run the drills is furnished by one of the largest air plants and longest supply mains in the world. A 10-inch air main runs the full length of the cut, $9\frac{1}{2}$ miles, with an extension at the south end to Miraflores. To equalize the pressure, compressors are located at three points, one near each end of the line, at Las Cascadas and Rio Grande, respectively, and one near the center at Empire. Each of these plants has four compressors of a capacity of 2,500 cubic feet to 100 pounds pressure per minute, or 30,000 cubic feet per minute in all. It will be necessary to install two additional compressors on account of the greater proportion of rock that is now encountered.

The smaller size steam shovels weigh 70 tons and have $2\frac{1}{2}$ -yard dippers, and the large size shovels 95 tons and are equipped with 4 and 5 yard dippers. They are self-propelling and are able to make a cut over 20 feet deep. There are 100 in all. In working down from one level to the next lower level it is customary to start shovels at different points to dig the center trench, called the "pilot cut," which is 34 feet wide at the bottom, 50 feet at the top, and from 15 to 20 feet deep. These pilot shovels are followed up by shovels widening the cut on each side, each taking $26\frac{1}{2}$ -foot slices. The great problem is to keep the shovels supplied with cars, so that they can work continuously; under the best of circumstances, owing to

repairs, accidents, and delays due to moving the shovel forward, as well as waiting for cars, etc., it is not possible to keep the shovels working more than two-thirds of the time. During the past two years the average output per shovel has increased over 50 per cent. In March, 1909, the shovels in the Central division averaged nearly 36,000 yards for the month. The largest monthly record for one shovel was made in October, 1908, when a shovel loaded 58,483 cubic yards. The largest day's record was in February, 1909, when during eight hours one shovel excavated 3,941 cubic yards, which is equivalent to the work of over 600 men. There is great rivalry between the shovel engineers to make the best record. The crew of the steam shovel consists of 1 engineer at \$210 per month, a cranesman at \$185, and a fireman at \$83.33; also from 6 to 10 laborers, called "pitmen," who are kept busy moving the track forward on which the shovel runs and on various other operations. The working day for the shovel is eight hours—from 7 to 11 and from 1 to 5. At 5 o'clock the various supply and repair trains start out promptly from the different yards for the "cut," where they spend the night making repairs and getting ready for the next day's work. This consists in supplying each shovel with a ton and a half or so of coal, with oil, and other supplies. Repair gangs are required to make all the necessary adjustments and repairs so that the shovel can begin digging at 7 o'clock the next morning. It is seldom now that shovels have to be taken into the shop for general repairs, as a sufficient supply of extra dippers, booms, dipper sticks, swinging circles, and other main parts of the shovel are kept on hand, and when a breakdown occurs it is only necessary to replace the part in question in the field with one of the spare parts.

The large shops at Empire, where 600 men are employed, are devoted to repairs of steam shovels and steam-shovel parts. Repair parts are purchased in the United States unless they can be manufactured more cheaply on the Isthmus.

The greater part of the excavated material is loaded onto long, flat, wooden cars with one high side, called "Lidgerwood flats." One thousand eight hundred of these cars have been purchased. Originally there were 16 cars to the train. It has since been found practicable to increase the number to 18. Each car has a capacity of from 18 to 20 cubic yards, or about 350 cubic yards to the train, making a load of about 500 tons. Each shovel is able on an average to load

from three to four trains per day. From Empire south, trains move down grade, coming out of the cut on the incline at Pedro Miguel, and thence run down to Miraflores dump, or to Balboa, where they dump into the Pacific to form the breakwater which is being extended to Naos Island. From Empire north, the trains move down grade, coming out on the main line at Las Cascadas or Matachin, or taking to the relocated line on the east side of the canal at Bas Obispo, where the spoil is dumped on the relocated line between Gamboa Bridge and Caimito. At the present time all hard trap rock suitable for use in Gatun dam is being loaded onto trains of from 25 to 30 steel dump cars and hauled from Bas Obispo to Gatun.

A dozen or more dumps were maintained in former days. On account of the deepening of the cut and from considerations of economy, it has been found desirable to concentrate the disposition of spoil in a few large dumps. The dump at East Balboa requires an 11-mile haul. At Miraflores dump nearly 4,000,000 yards have been dumped within an area of about 260 acres. The largest dump is at Tabernilla, where 10,000,000 yards have been spread over an area of little less than 1 square mile. The average haul north is 12 miles to Tabernilla, $5\frac{1}{2}$ miles on the relocated Panama Railroad, and 25 miles to Gatun.

The work requiring the largest number of laborers is in moving and ballasting track. In Culebra cut alone there are 51 miles of track, and in the whole Central division there are 194 miles of track exclusive of Panama Railroad tracks. On an average about 1 mile of track per day is moved in Culebra cut and on the dumps in the ordinary conduct of work.

One thousand one hundred all-steel dump cars have been purchased varying from 12 to 20 yards in capacity. The 12-yard cars are dumped by hand and the large steel cars are dumped by air. Over 650 of the small French dump cars have been used at various times, and by executive order the application of the interstate commerce law to the Isthmus as regards couplers and air brakes, specially excepted French dump cars for one year from July 1, 1909, during which time their use will be required. The wooden flat cars called "Lidgerwoods" are unloaded without hand labor by a 5-ton steel plow, to which is attached a $1\frac{1}{2}$ -inch steel cable. The plow is operated by a Lidgerwood unloader capable of exerting a 60-ton pull,

which in turn is operated by steam furnished from the locomotive to which it is attached, the plow being drawn forward by this cable winding around the drum of the unloader, and the dirt being thus forced over the side of the cars. When working smoothly the train is unloaded in five minutes and starts back immediately to the cut.

On an average, the cars make two round trips per day, and in the Central division over 200 dirt trains, including both steel dump cars and Lidgerwood flats, are loaded and dumped each day. The ridge of rock and earth which is plowed off the cars is leveled by a spreader which operates on the same principle as a snow plow. In moving tracks on the dumps, a labor-saving device called a "track shifter" is employed which performs the work of 500 laborers. It consists of a derrick mounted on a steel flat car with a projecting arm to which hooks are attached, by which a section of the track ahead of the car is raised, after which, by means of a side arm carrying another hook, the suspended track is moved over any distance up to 8 or 9 feet. The usual throw of the track is from 4 to 5 feet.

Locomotives are housed at night in engine houses at various points along the line, the principal ones being at Pedro Miguel and Las Cascadas, where they are coaled and given light running repairs by a night gang. Every morning they begin to leave the engine houses promptly at 6.30, and in five minutes the 30 or 40 locomotives have departed. One hundred and sixty large American locomotives have been purchased by the Commission. In addition, the Panama Railroad has 82 locomotives, and about 130 old French locomotives have been repaired and put into Commission service.

The number of cars in use by the Commission is nearly 4,500, and in addition there are a large number of unloaders, plows, spreaders, track shifters, cranes, pile drivers, and smaller pieces of miscellaneous equipment. Locomotives, cars, and other equipment, except steam shovels are repaired at the Gorgona shops, where a force of 1,000 men is employed. The French company started these shops, which have since been rebuilt and enlarged. An iron foundry and a brass foundry are also located at the Gorgona shops.

GATUN DAM.

Due primarily to its size, Gatun dam has received perhaps more than its share of attention in the United States. There is nothing especially difficult or complicated about this dam, and many dams

have been successfully built in the United States to withstand much larger pressures and greater heads of water than the Gatun dam without being given one-hundredth of the attention. Gatun dam fills the opening between the hills at Gatun, through which the Chagres River flows to the sea. It will consist of a water-tight center or core composed of sand and clay mixed in proper proportion and deposited hydraulically; that is, by being pumped in by dredges. This center core is to be confined by a rock wall on each side. The dam rests on impermeable material of sufficient supporting power. The site and the plans have been examined by the leading specialists in engineering construction of this kind in the United States, and both the foundation and superstructure have been pronounced, without qualification or reservation, to be entirely and absolutely safe. The last special engineering committee accompanied President-elect Taft to the Isthmus in February, 1909, and spent two weeks studying various canal matters. It thoroughly approved and indorsed the project as a whole and in part. A few changes in detail on lines of economy which were suggested are being followed.

The locks and the spillway may be described generally as appurtenances of the dam. The spillway consists of a concrete-lined opening cut through a hill of rock along the line of the dam near the center, supplied with gates of suitable design to allow the lake level to be regulated. The locks are built in an excavation at the east end of the dam, in rock, and afford means for passing vessels in and out of the lake on the Atlantic side. They are operated in the manner usual for such works.

The dam proper is about 7,500 feet long over all, measured on its crest, and for only 500 feet of this length will it be subjected to a pressure of 85 feet of water, as the natural surface on which it is built rises rapidly after passing by the old bed of the Chagres River. For only about half of its length will the head of water on the dam be over 50 feet. Hard rock underlies the dam near the surface of the ground except for about one-quarter of its length, where the rock dips down to a minimum depth below sea level of from 195 feet in the depression east of the spillway to 220 feet in that west of the spillway. These depressions or valleys have during past ages filled up, and, measured from sea level down, the first 80 feet consists of

sand and clay; the next 100 feet or so is stiff blue clay; the last 20 feet is a conglomerate, composed of sand, shells, and stone. This material is all impervious and of sufficient bearing capacity to support the dam, and thus fulfills the essential requirements. The entire area to be covered by the dam and adjacent territory has been probably more carefully examined by borings, test pits, etc., than that for any other similar structure.

The construction of the dam is being carried on by first building two lines of rock, composed of spoil from the canal and lock excavation, about 1,200 feet apart and parallel to the center line of the dam. The south or upstream pile or "toe," as it is called, has a height of about 60 feet and the downstream toe about 30 feet. These rock toes confine the body of the dam between them, which is to be mainly of impervious material pumped in by dredges. At the bottom this impermeable core will have a width of about 860 feet, outside of which the body of the dam will consist of spoil, which can be placed with the least expense. Outside of the toes are the waste piles for the spoil of neighboring excavation. These piles will slope down gradually and extend indefinitely, so far as material is available. The total thickness of the dam at the base between the outer edges of these waste piles will be fully 2,000 feet. The thickness of the dam at the water surface, elevation plus 85, will be 398 feet. The top of the dam will be 30 feet above the water level and have a width of 100 feet. The top and upstream slope will be thoroughly riprapped. At the present time the rock toes east of the spillway have been carried to full height, and three dredges are working twenty-four hours daily in pumping in impervious material to form the core between them. From 300,000 to 400,000 yards of material are handled by these dredges per month. The spillway has a channel 300 feet wide and is designed for a maximum run-off of 140,000 cubic feet per second. The concrete floor has been laid, and the side walls are well under way.

Last November, while the south toe was being constructed where it crossed the old French canal channel, the weight of the superimposed rock on the soft silt and mud, which had been collecting since the French stopped work twenty years ago, squeezed the mud out at the bottom of the French canal, from which the water had just been pumped. The crest of the pile of rock slid down and in for a distance of about 200 feet. The vertical movement was about 20 feet at the

top, but at the bottom of the rock pile was only 8 feet. The bank on the south side of the rock pile was entirely undisturbed. Several other slight movements had previously occurred without anything being thought of it. This local disturbance, happening in conjunction with a flood in the Chagres River, formed the basis of the sensational stories which were published in the United States. This happening caused no anxiety on the Isthmus, and hardly passing interest.

GATUN LOCKS.

The excavation for the locks at Gatun is well under way. Three-quarters of the 5,500,000 yards have been excavated. The excavation for the upper lock is practically completed, and the mixing and placing of concrete begins this month. The general plan of the upper locks may be taken as typical of all the locks. The locks are in pairs each having a width of 110 feet and a usable length of 1,000 feet. Each lock consists of a chamber, with walls and bottom of concrete, and with water-tight gates at the ends. The level of water in the locks is regulated through openings in the bottom, by the operation of valves in the side and center walls, which permit water to flow into and out of the locks by gravity. These locks are the largest that have ever been designed.

The controlling principles which have been followed in the design of the locks have been:

First, to make them safe, and second, to make them adequate in size and arrangement.

To attain the former, attention should be particularly directed to five devices which will be used. The fundamental principle has been followed that in all cases there shall be at any time not less than two barriers separating a high level from that next below. In carrying out this principle there are two gates at the upper end and two gates at the lower end of the upper lock. The double gates will be operated simultaneously. Another safety device is a chain stretched across the lock near the surface of the water and passed around fixed capstans on the walls. This device is so designed that by the application of frictional resistance at the proper varying rate it will arrest a 10,000-ton vessel moving at a speed of 6 miles an hour. When not in use it will lie in a groove in the lock floor. The results of serious mishaps to the gates and locks are guarded against by mov-

able dams above the upper gates. Each dam consists of a swing drawbridge from which wicket girders can be lowered one at a time, the upper ends being supported by the bridge and the lower ends by a sill in the bottom of the entrance. These wicket girders being lowered in horizontal tiers one at a time gradually diminish the area of the waterway. This dam is so designed that the flow of water through the locks, with the gates once opened, could be checked in less than an hour. The safety devices already mentioned, namely, twin locks, duplicate gates, cable protection, and movable emergency dams, have all been successfully tried separately on different locks in this country and abroad. In no case has it ever been deemed necessary to install all of them in the same work.

In addition, a further safeguard will be adopted to minimize the chances of accident. Practically all recorded accidents to locks in recent years have occurred through some mistaking of signals between the pilot house and the engine room while the vessel has been passing through locks under its own steam. To obviate this source of danger, it is proposed to provide on the walls of the locks electric locomotives, which under proper control will tow vessels through the locks, there being one locomotive on each side of the lock forward and astern, or four in all, vessels not being allowed to move their propellers meanwhile.

The gates consist of two leaves and are massive steel structures 7 feet thick, 65 feet long, and from 47 to 82 feet high. They will weigh from 300 to 600 tons each. Eighty-four leaves will be required for the entire canal, the total weighing 43,000 tons. Intermediate gates will be used in the upper locks in order to save water, if desired, in locking small vessels through, the gates being so fixed as to divide the locks into chambers 550 and 350 feet long, respectively. Ninety-five per cent of vessels navigating the high seas are less than 600 feet long.

The adequacy of the water supply for the demands of commerce has never been seriously questioned. Data on this point is available from many years' investigations and study. During three-quarters of the year the rainfall is ample. During the remainder there is practically no rainfall, and therefore enough water must be stored during each rainy season to carry over the succeeding dry season. The advantage of the enormous storage capacity of Gatun Lake for this purpose is thus seen, and it is intended to allow the water

to rise in the lake to elevation +87 at the end of each rainy season, and it can lower $5\frac{1}{2}$ feet from this elevation without reducing the depth through Culebra cut below that in the sea-level approach on the Atlantic side at low water. In other words, Gatun Lake will, during the rainy season, store over 5 feet of water that can be used during the dry season.

According to conservative calculations the canal as designed will have ample water supply for as many lockages per day as can be passed through the canal, which is estimated to be 48 for the twin locks. This will amount to fully 80,000,000 tons per annum, and the canal will not be called upon to take care of tonnage in excess of this amount until a very distant day. Should the day ever come when greater capacity is needed, other locks paralleling the present ones could be built, and the storage of additional water to carry over the dry season could be obtained from a dam at Alhajuela. The tonnage passing through the Suez Canal is about 21,000,000 gross tons per year and through the Sault Canal 40,000,000 gross tons per year.

The main culverts, 18 feet in diameter, through which the lock chambers are filled, are located in the walls and connect with the lock chambers through lateral culverts opening upward through the lock floors, which are controlled by valves of the Stoney type; that is, gate valves moving on rollers in frames to reduce friction. The lateral culverts which cross the floor are 72 feet center to center, with openings 18 feet apart. By thus distributing the water over the entire floor of the lock, currents and eddies are reduced to a minimum when the lock is filled or emptied quickly. The locks can be filled either from the side culverts alone, through the middle culverts alone, or through both together. With both culverts turned on, the time of filling the lock would be a little over eight minutes, or over 3 feet per minute. It is not expected, in the ordinary operation of the locks, to fill or lower same in less than about fifteen minutes, or at a rate of about 2 feet per minute.

Electricity will be used not only to tow vessels through the locks, but also to operate all the gates and valves, power being generated by water turbines from the head created by Gatun Lake. Electric energy is likewise being used to operate the machinery and plant used in constructing the locks. At Gatun and at Miraflores each power plant consists of three 1,500 kilowatt turbine generators,

steam being furnished by six 400-horsepower boilers. Twenty-five cycle alternating current is generated. About 2,300,000 yards of concrete will be placed in the Gatun locks and spillway. The Pedro Miguel locks and dams and the Miraflores locks, dams, and spillway, altogether, will require about the same amount.

Concrete will also be required to line a portion of Culebra cut under water amounting to almost half a million yards, making a total of almost 5,000,000 cubic yards of concrete.

The strata which have been pierced in excavating for Gatun locks consist successively of red clay, argillaceous sandstone, conglomerate, and soft sandstone (which is water bearing); and underneath these strata, tufa and argillaceous sandstone, and finally fine, compact, impervious argillaceous sandstone are to be found. The water carried by the soft sandstone is small in amount and comes from a remote source under pressure from the southeast. The strata dip to the north. The floor of the locks at Gatun rests upon either the sandstone or conglomerate, and there will be a thickness of not less than 20 feet of concrete, or concrete and hard, impermeable rock between the bottom of the locks and the water-bearing sandstone.

Concrete curtain walls 6 feet thick and from 8 to 18 feet below sea level are being built around the upper locks, from the sill of the emergency dam to the lower end of the intermediate gate abutments, to act as a water cut-off where the concrete is less than 20 feet in thickness, and old French rails have been embedded in the underlying rock to act as anchors for the concrete, tying it to the portion of the rock which acts as the floor.

The construction plant is complete and elaborate. Broken stone for concrete is brought from a large quarry and crushing plant at Porto Bello, 18 miles to the east of Cristobal, which has a capacity of 2,400 cubic yards in eight hours, and sand from old Nombre de Dios, beyond. Upward of 2,000 yards of concrete will be laid daily, working in two shifts. Cement will be brought from the United States in two large steamers bought for the purpose, each of which can carry 45,000 barrels. Nearly 5,000,000 barrels will be used.

Pedro Miguel locks and dams.—At Pedro Miguel there is to be a single set of locks with one lift of 30 feet. The locks are similar to the Gatun locks in design. The dams connecting the locks with the near-by hills on each side at Pedro Miguel are not large. To the west

the dam is of earth, 1,400 feet long with top 40 feet wide at elevation +107. The maximum head of water against this dam will be 40 feet. The dam has an impermeable core of solid material 140 feet thick. The east dam will have a concrete core 550 feet long, 4 feet wide at the top and 10 feet wide at the bottom.

Miraflores locks and dams.—At Miraflores there is to be a flight of locks in pairs, with two lifts of $27\frac{1}{2}$ feet each. The dams extend from the upper ends of the locks to the nearest hill on each side. The west dam is 2,300 feet long and runs practically parallel with the locks. It is of earth with a top width of 40 feet at elevation +70. The maximum height of water against this dam is 45 feet. The east dam will be of concrete 500 feet long, and a spillway having a capacity of 39,000 cubic feet per second will be built in this dam. There will be a power plant similar to the plant at Gatun in size.

Sand for making concrete for the Pacific locks will be brought from the peninsula of Chamè, lying to the west of Panama. Rock will be transported by rail from a quarry which has been opened on the west side of Ancon Hill. In handling the material for mixing and placing the concrete, 8 cantilever cranes will be used.

The foregoing constitute some of the salient features of the construction work. The work is being carried on with the greatest speed practicable, with due regard to economy, and everything on the Isthmus is subordinated to the construction work.

Forming a part of the Department of Construction and Engineering on the Isthmus are the Quartermaster's and Subsistence departments, the departments of Examination of Accounts, and Disbursements, and the Mechanical Division, and in the United States is the Purchasing Department. The office of the Chief Engineer is divided into four divisions. All of these departments and divisions have their special functions and duties.

The Disbursing Officer is the pay officer. The Isthmian pay rolls average about \$1,500,000 per month. American employees and European laborers are paid in gold. West Indian laborers are paid in silver. Over 42 tons of silver are paid out monthly. The pay train travels over the Isthmus once a month, from the 12th to the 16th, paying off all employees. From \$400,000 to \$450,000 of the monthly earnings of employees are used to purchase money orders on the United States and elsewhere. The hotel and commissary

receipts from commission employees are not far from \$300,000 per month. Probably \$250,000 or more is spent in Colon and Panama; and an equal amount in the Zone. What becomes of the balance is open to conjecture. Undoubtedly a large part of it is being saved.

The Examiner of Accounts has charge of the general books of the Commission and, with his force of 115 men, classifies all expenditures; handles the accounting for coupon books and meal tickets; examines claims and accounts presented for payment and prepares the proper vouchers; makes a monthly administrative examination of the Disbursing Officer's accounts and counts the cash in the hands of the Disbursing Officer every six months; inspects the books and accounts of all employees handling money and coupon books; checks all payrolls; examines and checks daily, time books of all hourly employees; reports misconduct of employees, misuse of property, and violation of rules and regulations in connection with the efficient and economical application of labor and material; handles employees' injury claims; and audits accounts of all revenue officers.

The Quartermaster's Department performs all duties in connection with the recruiting of laborers, the housing of employees, the construction and repair of buildings, the purchase of material on the Isthmus, the custody and issue of all material from storehouses, and the supplying of animal transportation. Under executive order, at the present time, no one not an American citizen can be employed on the gold roll. The gold employees number about 4,200, and their average period of service on the Isthmus is over two years. They are all furnished suitable quarters. The Commission inherited from the French a number of family quarters, and when it was necessary during the early days of canal construction to offer great inducements to get men down to the Isthmus, the furnishing of family quarters within a reasonable time was made a condition under which they were employed. In addition, a considerable number of new quarters have been built. Accordingly there are accommodations for about 1,500 families of gold employees. The Commission builds no family quarters for men employed after January 1, 1908, when this condition was changed, though, in case any family quarters become vacant, employees appointed after that date are eligible for assignment thereto. At the present time there are about 400 applications on file for family quarters. There is a surplus of bachelor quarters.

The cost of constructing quarters for bachelors averages from \$250 to \$500 per man, and for families from \$1,200 up. In addition to quarters, the Commission furnishes employees electric light, certain furniture, coal for kitchen stoves, distilled water, and medical service without charge. Employees may have thirty days' sick leave with pay per annum, and thirty days' injury leave, and monthly employees are allowed six weeks annual leave with pay.

The number of silver employees on the rolls in any one month is much greater than the number working on any one day. The average West Indian laborer will not work as long as he has a dollar in his pocket, and it is a common saying that if such a laborer's pay is doubled he will only work half as many days. The result is that at present the number of silver employees at work on any one day is about 23,000, whereas the pay rolls for the month will show over 30,000 names. The Panama Railroad employs in addition a force of about 6,500, including the commissary force. Silver employees are housed generally in barracks, which, on an average, at the present time, contain from 20 to 30 men. A number of old French buildings have also been fitted up so that they can have a room to live in with their families if they so desire. Over 1,000 family quarters are thus provided for West Indian and 200 for European laborers. During the last year or two there has been a movement among the West Indian laborers to go into the "bush," where they put up a small shack, cultivate a small plat of ground, and feel thoroughly contented and comfortable, housing and feeding themselves independently of the Commission. At the present time less than one-fourth of the West Indians look to the Commission for their quarters and food.

The labor problem is one of the most difficult to solve on any construction work in the Tropics. In the early fifties the construction of the Panama Railroad was greatly handicapped by lack of suitable labor. The French met this same difficulty, and since American occupation the problem of getting labor, training it, and keeping it at work has been paramount. The greatest success has been attained through importing European laborers to compete with and set the pace for the West Indian laborers. Altogether nearly 12,000 laborers have been brought from Spain, Italy, and Greece, of whom about 4,000 remain at the present time. West Indian laborers have been recruited mostly from Bar-

bados, Guadaloupe, Martinique, Trinidad, and St. Kitts. In all, 23,000 West Indians have been recruited and brought to the Isthmus. In addition, many thousand Jamaicans and other West Indians have come at their own initiative. At the present time the problem can be said to have been solved, as there are more laborers on the Isthmus than there would be work for if they should want to work steadily.

The West Indian laborer is paid 90 cents for a day of nine hours, and is furnished three meals by the Commission for 30 cents, if desired. The Commission also furnishes him with quarters without charge. The European laborer receives \$1.80 for nine hours' work, and is charged 40 cents per day for three meals. He is likewise furnished with quarters without charge. The standard rate of pay for American mechanics and other hourly gold employees is 65 cents an hour. By act of Congress the eight-hour law applies on the Isthmus, and is rigidly adhered to. In 1906, by a supplemental act of Congress, alien unskilled labor was excluded from the provisions of the eight-hour law. The standard day for these alien laborers is nine hours.

The average compensation received by American employees is not far from \$150 per month. The average monthly compensation received by laborers and other silver employees, based on the number actually working in any one day, is about \$35.

The effects of the climate are especially felt by shop mechanics. The humidity of the atmosphere prevents sunstroke, however, and notwithstanding the heat, sunstroke, even among those working in the open, is unknown.

The life of Americans on the Isthmus has become established in grooves corresponding very closely to life in the United States. The Y. M. C. A. clubhouses in the larger settlements afford recreation, and there are social and other organizations of the same character as are to be found in the United States. There are over 1,500 American women who are sharing alike the comforts and discomforts of Isthmian life with their husbands, and about the same number of American children, not including wives and children of Panama Railroad employees.

Intimately connected with the housing and care of employees is their feeding and furnishing those who keep house with provisions

and supplies. This is done through the medium of the Subsistence Department, which maintains at all settlements where there are gold employees a hotel where meals can be obtained by an employee for 30 cents each. The European laborers are fed in what are called "messes," where for 40 cents a day they are given an ample supply of the food to which they are accustomed. Such of the West Indian laborers as are fed by the Commission eat at so-called kitchens. The West Indians furnish their own mess kit and, after obtaining the supply of food to which they are entitled by their meal ticket, are at liberty to eat it wherever they wish. There are eighteen hotels for gold employees, and forty-two messes and kitchens for silver employees. In 1906 a large hotel, the well-known Tivoli Hotel, was constructed at Ancon. This hotel is a rendezvous for all Americans on the Isthmus. Here various social organizations hold their regular dances, and it is the headquarters for celebrations of various kinds. It is the usual stopping place for American visitors. It is operated by the Subsistence Department so as to be self-supporting, and the charges are in accordance with this requirement. At the commissaries operated by the Panama Railroad not only provisions, including cold-storage articles, are kept, but also clothing and everything to meet the necessities of employees, which are sold at reasonable prices.

The cold-storage plant in Colon is operated by the Commissary Department, and a trip through this plant gives one a very good idea of the scale of operations on the Isthmus. From 75 to 80 tons of ice are made daily, which is sold at the rate of 40 cents a hundred pounds. The cold-storage supply of meats, vegetables, etc., is kept in this plant, and shipments are made daily along the line amounting to nearly 100 tons per day, including ice. Accessory thereto are various manufacturing plants, including the laundry and bakery, with the following daily output:

Bakery:

Loaves of bread.....	13,000
Rolls.....	2,400
Pies.....	290
Pounds of roasted coffee.....	625
Pounds of cake.....	450

Laundry:

Pieces.....	7,500
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There is also a plant which turns out 240 gallons of ice cream each day, which retails for 25 cents per quart.

The general purchasing officer of the Commission is in charge of the Washington office, as chief of office. He makes all purchases and inspections of material in the United States requisitioned by the Quartermaster's Department, and fills all vacancies in the "gold" personnel in accordance with civil-service requirements from lists of eligibles on file in his office or from certifications of the Civil Service Commission.

The foregoing represents, generally, the organization of the Department of Construction and Engineering. In addition there are two other coordinate departments, the office of the Secretary of the Commission and the Panama Railroad and steamship line, all under the Chairman of the Commission, the latter coming under his jurisdiction in his capacity as President of the Panama Railroad.

The Secretary of the Commission edits the "Canal Record," published weekly under the authority of the Canal Commission, handles requests received for information regarding matters in connection with the canal work, and hears and investigates grievances of employees.

DEPARTMENT OF SANITATION.

The importance of the sanitation of Panama, Colon, and the Canal Zone was early recognized and a committee of sanitary experts accompanied the Commission on its first visit to the Isthmus, in April, 1904, which led to the organization of the Department of Sanitation two months afterwards. Besides the care of the sick, the work of this department for the improvement of public health may be classed under two heads, viz: First, the sanitary service, which includes all work to eradicate yellow fever, and to reduce and control malaria and other diseases; and, second, the quarantine service, which prevents the importation by land or sea of bubonic plague, yellow fever, cholera, and smallpox. The work of the Sanitary Department under the member of the Commission who has been its head since it was organized has been phenomenally successful, and by removing the cloud which rested over the Isthmus from its insanitary and extremely unhealthful condition, and thus making it possible for Americans to live and work there in health and happiness, it has performed a service of inestimable value toward the construction of the canal. The

present condition has been reached only by persevering hard work. There have been 134 cases of yellow fever among employees and 34 deaths, but since 1905, nearly four years ago, not a case has been known. Similar success has attended the fight against malaria. In 1904, three-fourths of the Zone population were infected with malaria, and in the early days of canal construction the number of employees treated for malaria in hospitals in a year averaged over 80 per cent of the entire number. It is scarcely one-third of this at present.

In the last three years the total sick rate of employees has been reduced more than one-half, and the death rate more than two-thirds.

When we consider the handicaps in the way of insanitary conditions under which the French worked, we have increased admiration for what they accomplished. Over 1,200 men are carried on the rolls of the Department of Sanitation, and the expenditures amount to \$2,000,000 per annum. It will require constant work and unceasing vigilance to keep health conditions up to the standard which has been established. The total expenses of the Sanitary Department will amount, it is estimated, to about \$20,000,000, or a little over 5 per cent of the total cost of the canal. Of the total expenditures of the French, less than \$2,000,000, or hardly one-half of one per cent was charged up to hospital service, and practically nothing to sanitation.

The main hospitals are at Ancon and Colon. Ancon Hospital takes patients from the territory south of Tabernilla, and Colon north of Tabernilla. Ancon Hospital has about 1,450 beds in 37 wards, including 350 for the insane, and Colon Hospital has 400 beds in 13 wards. Ancon Hospital was established by the old French company in 1883, and from 1883 to 1889 over 5,000 deaths occurred at the hospital, 1,200 of which were from yellow fever. The insane asylum forms a part of Ancon Hospital, and operated in connection with the hospital is a laundry and a dairy. Employees receive medical attention without charge. There is a regular scale of charges for members of their families, private rooms, special nurses, etc. In addition to these main hospitals are dispensaries and sick camps in each settlement, with resident physicians to attend to those whom it is not necessary to take to the hospitals.

On Taboga Island, in Panama Bay, 10 miles from shore, is the sanitarium for convalescent patients, which was established by the

French Canal Company in 1885. It has accommodations for about 100 patients. There is a leper colony at Palo Seco, on the seashore west of Panama, with 31 patients.

The quarantine service is under a chief quarantine officer, with quarantine stations at Colon on the Atlantic side and on Culebra Island, 4 miles from shore, on the Pacific side.

The sanitary work proper in Panama, Colon, and in the Zone consists at present of the cleaning of streets and grounds, the collection and disposal of garbage, the extermination of rats and mosquitoes. The latter work requires draining low ground where water collects, cutting grass and vegetation, etc., which work is done by the forces of the construction divisions and quartermaster's department, under the supervision of the sanitary inspectors.

The Commission has provided for the religious welfare of its employees by the employment of a dozen chaplains of different denominations and by furnishing buildings in which to hold services. In addition, nonsectarian religious meetings are held in commission club houses under the auspices of the Y. M. C. A. The chaplains are carried on the payrolls of the Department of Sanitation. They visit the hospitals daily and perform such duties in connection with their calling as may be required. The Salvation Army has 7 stations and does active work. The headquarters building at Cristobal was erected by the Commission two years ago, and in addition to quarters for the officers has a reading room, dormitory, and restaurant.

The Department of Civil Administration was created to administer civil government within the Canal Zone; that is, it exercises the governmental rights conveyed by Panama to the United States in maintaining and protecting the inhabitants of the Zone in the free enjoyment of their liberty, property, and religion. The Chairman of the Commission, in whom is vested, by the President, the authority of the chief executive of the Canal Zone, has delegated that authority to a member of the Commission, who is known as head of the Department of Civil Administration. The work of this department is divided among the divisions of Posts, Customs and Revenues, Police and Prisons, Schools, Fire Protection, and Public Works; the offices of Prosecuting Attorney, Treasurer, and Auditor of the Canal Zone; and the judiciary. The latter include the supreme, circuit, and district courts of the Zone. The population of the Canal Zone is not

far from 70,000. The cost of government, paid from canal appropriations, is about three-quarters of a million dollars per annum. Taxes, land rentals, and postal receipts amount to a third of a million dollars additional. By authority of Congress, the latter are applied to the maintenance of the postal service, the support of public schools, the construction of Zone roads, etc.

There are 17 post-offices in the Zone. Seventy per cent of the mail matter handled is carried free under government frank. Receipts amount to about \$100,000 per annum. The expenses (including 40 per cent of the value of stamps, which is paid to Panama) are 50 per cent greater.

At the time of American occupation there were 327 saloons in the Zone paying from \$12 to \$60 per annum for retail license. At the present time there are 56 saloons paying \$1,200 per annum. The receipts from these licenses support the schools.

Rentals from agricultural lands and building lots amount to about \$25,000 per annum. Over 150,000 acres are owned by the Government, exclusive of Panama Railroad Company holdings. At the last session of Congress a bill was passed authorizing the leasing of public lands for a term of twenty-five years. Town lots are rented for from 5 to 30 cents per square meter per annum, which is equivalent to about from 46 cents to \$2.77 per 100 square feet. Agricultural land is rented for \$1.20 per acre per annum, not more than 125 acres being leased to one person.

The custom laws of the United States are enforced in the Canal Zone with the exception of the rates of duty which are as prescribed by the Republic of Panama. All commercial importations into the Canal Zone pay a duty to the Republic of Panama. The collector of revenues is administrator of estates and administers without charge on the estates of deceased Americans, who are employees of either the Isthmian Canal Commission or Panama Railroad, when the estate consists of personal property amounting to less than \$1,000. Fifty estates of a value of about \$11,000 were settled during the twelve months ended June 30th, 1909.

The police force numbers 250 officers and men and costs \$250,000 per annum. All are Americans except 96 West Indians, who are useful in maintaining order among their own race. Arrests average 500 per month. The penitentiary, containing 125 convicts, is located at Culebra.

The school system, under a superintendent, is similar to graded public schools in the United States. There are 12 schools for white children and 17 for colored children. High schools for white children are located at Culebra and Cristobal. About 650 white children are enrolled and 1,300 colored.

The fire department consists of 7 paid and 19 volunteer companies under a fire chief and affords protection to over \$20,000,000 worth of property. It costs about \$110,000, equal to about one-half of 1 per cent of the value of the property protected. During the past year there have been 78 alarms, with a total loss of less than \$3,000.

The Division of Public Works has supervision over the eight public markets, the two public slaughterhouses, and the construction and maintenance of roads and trails. Sixty miles of trails have been cleared and partially graded, 12 miles of macadam roads built, and 18 miles of macadam roads are either under construction or will be undertaken as soon as funds are available. Prison labor is used on road work so far as practicable. This Division is also charged with the operation of the waterworks and sewers, and maintenance of pavements, in the cities of Panama and Colon. It passes upon all applications for water and sewer connections, inspects plumbing, and keeps records of water consumed, for which it prepares bills and makes collections thereon. On June 30, 1909, there were 1,292 water connections in Panama and 464 in Colon. The annual collections for the year ended June 30, 1909, were \$66,348.45 in Panama and \$71,275.80 in Colon.

The judicial branch of the Canal Zone government consists of a supreme court, three circuit courts, and four district courts. The chief justice and the two associate justices of the supreme court are also the judges of the three circuit courts. In capital cases trial is by jury.

The Panama Railroad is operated as a corporation and, in connection with it, the Panama steamship line of six steamers, four of which have been purchased by the Commission and chartered to the Panama Railroad Steamship Line. The gross receipts of the company are not far from \$6,000,000 per annum. The stock is owned by the United States. The work of rebuilding the Panama Railroad, made necessary from canal-construction work, which is under the engineering forces of the railroad, is proceeding at a rate which will enable

the stretch between Gatun and Gamboa to be completed by the time the rising waters of Gatun Lake flood the present tracks crossing the bed of the lake. In less than two years the new line will be ready for operation between Colon and Gamboa, a distance of 31 miles. On the Pacific end traffic will be carried on the new line between Paraiso and Panama within a comparatively short time, there being little work remaining. So long as necessary the present tracks between Corozal and Pedro Miguel will be used by dirt trains. To date, on relocation work, over 1,500,000 cubic yards of material have been excavated and 5,000,000 yards placed in embankments. Twenty-two miles of permanent track have been laid. From 2,000 to 2,500 men are employed on this work. The work will cost about \$8,000,000.

Inquiry is often made as to the liability of danger to canal works from earthquakes. So far as records are available no such danger need be apprehended. Masonry structures of unsubstantial construction have been standing in Panama for upwards of two hundred years—ever since the old Spanish days. The Isthmus, in fact, is outside of the zone of earthquake disturbances, which are frequent both north of it and along the coast of South America. A seismograph has been installed in Ancon for the purpose of recording any tremors. The location of Panama with reference to the disturbances in Central America is not clearly appreciated everywhere in the United States. For instance, when Acapulco, in Mexico, was shaken in the latter part of July, some apprehension was felt as to the effects of this earthquake in Panama. Inasmuch as Panama is about as distant from the territory shaken as it is from South Carolina, it would have been more appropriate to have felt solicitude for the safety of the Gulf States. As a matter of fact, it has been proved, especially in the States bordering on the Pacific Ocean, that earth dams and large concrete structures imbedded in the ground are practically immune from injury from earthquake shocks no matter how severe, and such structures will remain unharmed where buildings of all classes would be destroyed. The earthquake bugbear, so far as the Panama Canal is concerned, may be relegated to the background.

As is well known, there is no other place on the globe where the temperature is so constant, day and night, from day to day and from one month to another. The average temperature is about 79° the

year round. The daily variation is seldom as much as 20° ; in fact, in the shade, the mercury rarely gets out of the seventies and eighties either night or day, winter or summer. Taking the average monthly temperatures, the variation for the twelve months is only about 3° . Compare this with the variation in average monthly temperature, of Washington, D. C., which is about 43° . Panama owes its relief from the scorching heat of the tropical sun and its nights of even temperature to the belt of aqueous vapor which hangs over it and permeates the atmosphere. This makes the conditions different from what one would expect in the vicinity of the equator. The humidity is always high, usually over 85 per cent, and this is the most disagreeable feature of the Isthmian climate. It is necessary, however, and is preferable to the heat which would otherwise be felt.

Among important matters in connection with canal construction are:

First. Its cost.

Second. How much money has been spent to date.

Third. How much work has been accomplished; and

Fourth. When will it be finished.

The cost of an 85-foot level lock canal as estimated by the Board of Consulting Engineers in 1906 was about \$140,000,000, not including expenses of the Canal Zone government, of the Department of Sanitation, or the \$50,000,000 paid to the French Canal Company and to the Republic of Panama. As estimated in December, 1908, the cost will be about \$298,000,000, with the same items excluded, or about \$158,000,000 in excess of the original estimate. Of this excess, \$100,000,000 is for construction work and is due to the fact that the present plans provide for increased width of channel, increased size of locks, etc., which have resulted in an increase of over 50 per cent in the amount of work to be done as compared with the estimate of 1906. The 1906 estimate was based also on the ten-hour day, while the eight-hour day has been established by act of Congress, which has increased the cost of skilled hourly labor 20 per cent. The increase in cost of "Administration, engineering, and contingencies" is due to the fact that the 20 per cent added to the 1906 estimate to cover same was totally inadequate. It was sufficient for the "General expenses" of the work, but did not in addition make allowance for roads, waterworks, and sewers, which will cost \$12,000,000; for buildings which will cost over \$14,000,000; for

double tracking the Panama Railroad, purchase of additional steamers, docks, and wharves leased to the Panama Railroad, and loans to the Panama Railroad, together amounting to over \$12,000,000, etc. The total estimate of \$140,000,000 in 1906 did not include the expenses of the Department of Sanitation and Zone government, which are estimated to cost about \$27,500,000, and the \$50,000,000 paid the French Canal Company and Panama.

Work is proceeding in accordance with the estimate of 1908, amounting to \$297,766,000 for engineering work, to which should be added \$27,500,000 for sanitation and civil administration and \$50,000,000 paid to the French Canal Company and to the Republic of Panama, making a total of \$375,201,000. Of this amount, 56 per cent, or \$210,000,000, has been appropriated and estimates have been submitted for the action of Congress next December amounting to \$48,000,000, which will be sufficient to carry the work up to June 30, 1911, and when these funds have been expended the canal will be about two-thirds completed. One hundred and sixty-five million dollars is yet to be appropriated, and if the \$48,000,000 asked for is appropriated by the next Congress there will remain \$117,000,000 to be appropriated after the next session of Congress.

A good deal has been said about the issue of Panama Canal bonds in connection with appropriations. The bonds and the appropriations are two entirely separate matters. By paying for the cost of the canal out of current Treasury funds no bonds would be necessary. The bonds are provided—

First. To distribute the cost of the canal over a period of years in the future, to be paid when the bonds fall due, and

Second. To insure sufficient funds being in the Treasury to enable canal construction work to be continued without interruption.

The special act of 1902 authorized a bond issue of \$130,000,000. This was not expected to defray the entire cost of the canal, but only to distribute a portion of the cost of the work over the future years. The only estimate available at that time was that made by the Commission of 1901, which reported on the relative advantage of the Panama and Nicaragua routes, which estimate amounted to about \$144,000,000. This did not include either payments to the French Canal Company and to the Republic of Panama or the expenses of sanitation and civil administration.

Just before adjournment two weeks ago Congress authorized the issue of additional bonds toward the construction of a canal up to the full amount of the estimate for a lock canal, \$375,201,000. This action further confirmed and finally fixed the policy of the country in regard to the completion of the lock canal and removed the only possible obstacle to its progress, viz, lack of funds.

In accordance therewith, appropriations of from \$45,000,000 to \$50,000,000 for the next two years; from \$25,000,000 to \$35,000,000 for the following two years, and \$10,000,000 for the latter half of the calendar year 1914, will enable the canal to be opened and ready for use by January 1, 1915.

The principal items entering into the completed canal are:

First. Excavation;

Second. Concrete for locks and spillways; and

Third. Embankment and fill for dams, breakwaters, etc.

The total excavation required for the completed canal will amount to about 174,500,000 cubic yards, which is equivalent to a cube measuring nearly 1,700 feet on a side.

Concrete amounting to 4,850,000 cubic yards will be required, which is equivalent to a cube measuring over 500 feet on a side.

Embankment and fill required for the dams will amount to about 23,000,000 cubic yards, which is equivalent to a cube measuring over 800 feet on a side. Three and a half million cubic yards of material will be used as back fill for the locks, and 5,700,000 cubic yards for the Atlantic breakwaters.

Of the excavation, about 82,000,000 cubic yards were completed to August 1, 1909, or 47 per cent. Excavation is proceeding at the rate of about 35,000,000 cubic yards per annum.

Concrete has been laid to the amount of about 45,000 cubic yards. The laying of concrete in the Gatun and Pedro Miguel locks starts this month, and will continue during the rest of this fiscal year at an increasing rate that will soon reach 100,000 cubic yards per month.

To August 1, 1909, backfill and embankment had been placed amounting to about 4,400,000 cubic yards. This work will continue at the rate of from 400,000 to 500,000 cubic yards per month.

On July 1, 1909, the cost was, in round figures, as follows:

Department of Construction and Engineering.....	\$95,100,000
Department of Sanitation	8,800,000
Department of Civil Administration.....	2,900,000
Total.....	106,800,000

In addition to the above there should be added the \$40,000,000 paid to the French Canal Company, \$10,000,000 paid to the Republic of Panama, \$4,000,000 loaned to the Panama Railroad Company, and \$5,500,000 for material and supplies which have been purchased and are on hand, and for other similar items, which may be considered as assets, not having been yet applied to the work. In other words, cash had been expended from congressional appropriations to July 1, 1909, amounting to \$166,300,000, or nearly 45 per cent of the total estimated cost.

The foregoing is a statement of the present condition of work. An endeavor has been made also to trace the growth of the canal idea and to indicate that it is not a matter in which the United States alone is interested, but is an enterprise from which other nations will benefit and which the whole world demands shall be completed. The United States entered upon it appreciating its interest and responsibilities and its mission among the nations of the world, and in so doing committed itself to a project which time had shown was too large for any individuals or corporation to carry to a successful termination.

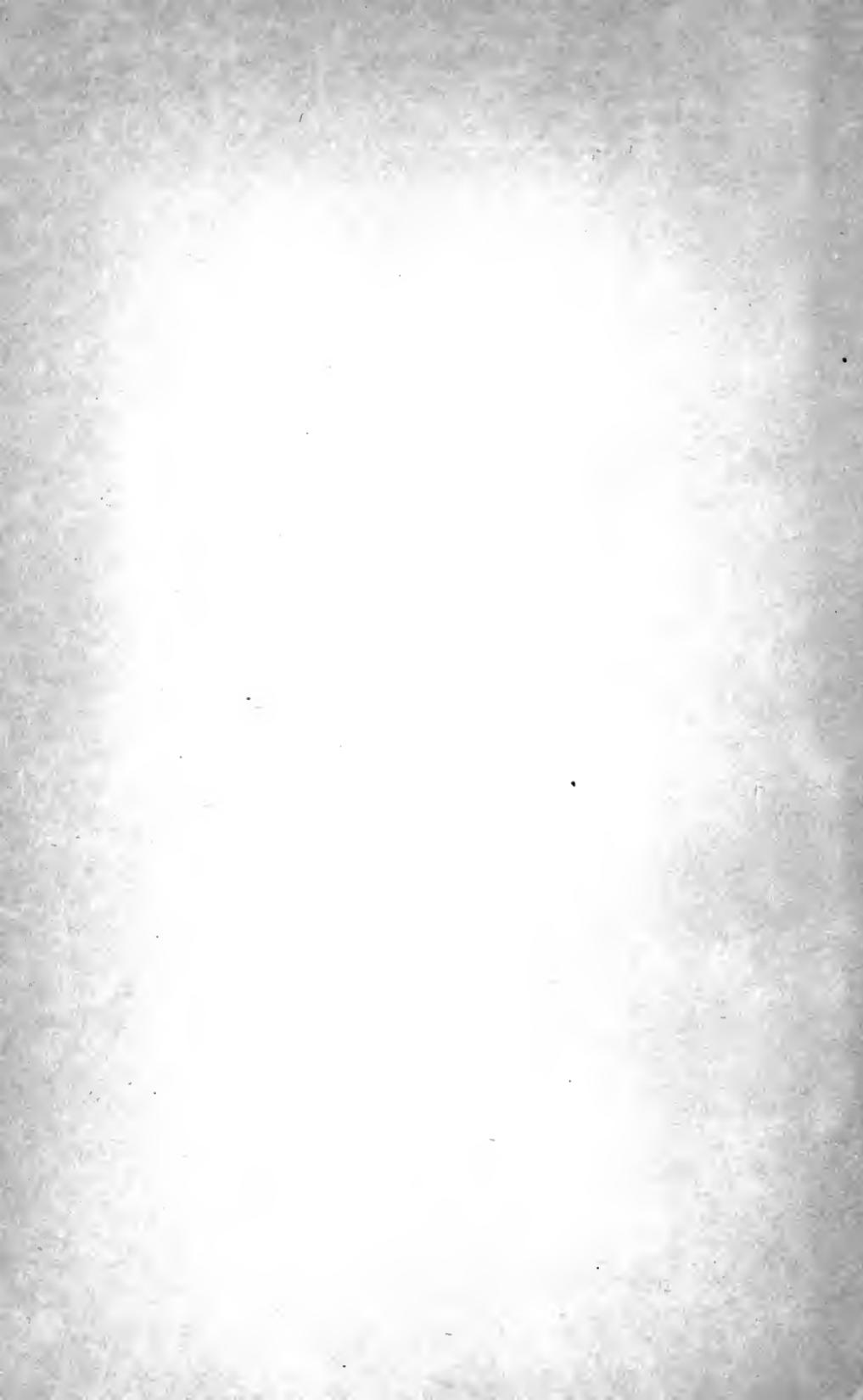
There have been some who at various times have thought that the difficulties will be too great, the cost excessive, or the returns insufficient. There need be no fears on these points. The pride of the American people can not be measured by dollars and cents.

Moreover, the time to consider such matters passed when the United States committed itself to a work from which it could not afterwards recede without great loss of prestige.

The facts are plain; the project is feasible; the work is well on toward being half completed; bonds have been authorized to the full amount of the estimate for a lock canal.

It will be finished as quickly as possible, and there should now be no looking backward.

The present plans are the best, the work is well in hand, and within about five years communication between the Mississippi Valley and the Pacific coast by water, via the Isthmus, will be open.





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